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ABSTRACT

The sentence processing abilities of a conduction aphasic adult woman with a documented phonological coding deficit were investigated in tests of auditory and visual sentence comprehension of reversible active and passive sentences and spatial prepositions, sentence production through story completion and picture description, and repetition of active and passive sentences and relative clause sentences that were reversible, irreversible, or semantically improbable. The subject showed a semantic comprehension deficit, relying heavily on word order formation to make grammatical role assigments. Production tests revealed a generally intact ability to generate a variety of sentence constructions, although there were frequent errors in the use of grammatical morphemes in the written productions. The repetition tasks were used to identify the processing strategies that the subject used under heavy memory load conditions. It was possible to identify the independent operation of processes based on representations of semantic information, word order, and grammatical morphemes, and it was found that the interactions between these processes clearly differ depending on the nature of the task. (Author/MSE)

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The sentence processing abilities of E.A., a conduction aphasic with a documented phonological coding deficit, were investigated in tests of sentence comprehension, production and repetition. E.A. showed a syntactic comprehension deficit, relying heavily on word order information to make grammatical role assignments. Production tests revealed a generally intact ability to generate a variety of sentence constructions, although there were frequent errors in the use of grammatical morphemes in the written productions. The repetition tasks

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were used to identify the processing strategies E.A. used under heavy memory load conditions. E.A.'s semantic and syntactic processing capabilities and the role of the phonological code in normal sentence processing are discussed.

Consequences of a phonological coding deficit on sentence processing[1]

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Abstract

The sentence processing abilities of E.A., a conduction aphasic with a documented phonological coding deficit, were investigated in tests of sentence comprehension, production and repetition. E.A. showed a syntactic comprehension deficit, relying heavily on word order information to make grammatical role assignments. Production tests revealed a generally intact ability to generate a variety of sentence constructions, although there were frequent errors in the use of grammatical morphemes in the written productions. The repetition tasks were used to identify the processing strategies E.A. used under heavy memory load conditions. E.A.'s semantic and syntactic processing capabilities and the role of the phonological code in normal sentence processing are discussed.

The analysis of selective deficits in brain-injured patients has provided important information about the independence of specific cognitive codes or processes within the language system. For instance, hypotheses about the functional independence of visual and phonological pathways leading to word recognition are supported by evidence of selective impairments in patients with acquired reading disorders (Coltheart, 1981). The role of these basic operations tends to be obscured in the analysis of more complex language tasks, such as sentence and discourse processing, not only because of the number of operations involved but also because intact adults may display flexibility in combining these operations. In this paper we use neuropsychological data to examine sentence processing in a patient with a specific impairment in phonological coding. The pattern of abilities and deficits that emerges can be used to clarify the role that the phonological code plays in normal sentence processing.[2]

The sentence processing data reported here were collected from E.A., a conduction aphasic with the primary repetition disorder and the good spontaneous speech and comprehension that characterize the syndrome. A detailed analysis of E.A.'s repetition disorder has been reported elsewhere (Friedrich, Glenn & Marin, 1984). In general, E.A. was similar to other patients with repetition deficits (e.g., Warrington & Shallice, 1969; Caramazza, Basili, Koller & Berndt, 1981; Vallar & Baddeley, 1984a) in that her performance on short-term memory tasks was severely impaired and showed no evidence of the use of phonological storage. For example, she showed better recall with visual than auditory

presentation (2.4 items versus 1.5 items), the opposite of the normal pattern. Further, her serial position curve showed no recency effect, that portion of the recall curve thought to reflect recall from a phonological buffer. Normal subjects usually show considerably worse recall performance for phonologically similar letters than for phonologically dissimilar letters, even with visual presentation (Conrad and Hull, 1964); E.A., however, actually showed somewhat better performance in the phonologically similar condition. The fact that E.A. could repeat single words and had an impaired memory span with both pointing and vocal responses showed that the reduced span was not due to articulatory or "reproduction" limitations.

Additional analysis demonstrated a fundamental phonological coding impairment that was independent of memory demands. Although E.A. could repeat single words accurately, she relied on a semantic route rather than the direct auditory-to-articulatory route that intact adults use (McLeod & Posner, 1984). In addition, E.A. performed poorly in identifying and discriminating individual stop consonants. She was, however, able to reproduce sequences of tones up to seven items in length. This combination of abilities and deficits led Friedrich et al. to conclude that E.A. had a specific impairment in phonological coding, one consequence of which was a severe deficit in verbal memory (see also Allport, 1984).

Normal Sentence Processing.

The role that phonological coding and short term memory play in sentence processing is not entirely clear from existing

evidence. Most current models of sentence comprehension and production assume a "working memory" as a component of the system (e.g., Frazier & Fodor, 1978; Bock, 1982), although the mechanisms and operation of working memory within these models remain relatively vague and ill-defined (Monsell, 1984). Working memory is currently viewed as a complex system, encompassing several subsystems for the temporary storage of different types of information, including phonological, visual and lexical, among others (Baddeley & Hitch, 1974; Hitch, 1980; Monsell, 1984). At least two mechanisms specifically related to phonological coding have been identified: a relatively passive "input register" and an articulatory loop used in subvocal rehearsal (Hitch, 1980). However, empirical analyses of sentence processing have addressed the role of phonological coding in a general way, without distinguishing these two mechanisms.

There is some evidence that the retention of phonological information in short term storage does play an important role in sentence comprehension (see also Hitch, 1980). Investigations of this issue with normal subjects have usually employed a reading task with concurrent articulation or shadowing which is presumed to prevent phonological recoding of the visual information. Kleiman (1975) showed that shadowing did not have an effect on semantic processing at the single word level although it did have a detrimental effect on judgments of sentence acceptability. Further studies by Baddeley & Lewis (1981) and Abernathy, Martin & Caramazza (Note 1) have shown that the concurrent articulation effect is specific to the detection of syntactic anomalies such

as order errors or auxiliary - verb disagreements.

There is less direct evidence of the importance of phonological storage for syntactic processing in auditory comprehension. However, studies by Jarvella (1970, 1971) and Caplan (1972) suggest that sentences are held in a phonological form until clausal analysis is complete. Both of these studies found that verbatim recall of an auditorily-presented sentence was better for information within the current clause than from a previous clause, even when number of words intervening between presentation and recall was equated. These results suggest that a phonological form is retained while syntactic analysis of a clause is being carried out. However, once this analysis is complete and a semantic interpretation of the relationships between content items has been made, the phonological information is rapidly lost (see also Sachs, 1967; Wanner, 1974).[3] Hitch (1980) has suggested that this type of storage is a function of the input register in particular.

Thus far, we have considered the possible role of phonological storage in comprehension. There is less information about the role of a phonological storage system in sentence production. Models of speech production implicate a working memory system (e.g., Bock, 1982) and certainly on intuitive grounds there would seem to be a need to retain the message and the overall plan of the sentence as it is being expressed. There is evidence from speech error data that prior to the final phonetic specification of the intended output there is an abstract phonological representation of a phrase (Garrett, 1975; 1980). In addition,

Ellis (1979, 1980) has shown a striking correspondence between spontaneous speech errors and recall errors in short term memory tasks: both types of errors are sensitive to vowel context and featural similarity, for instance, and in both cases consonant reversals are more frequent than vowel reversals. On this basis Ellis has suggested that the phonological store underlying short term memory also mediates speech production.

Thus, data in the normal literature suggest a role for a phonologically- based short term memory in both speech production and comprehension. At least from the work on comprehension, there is evidence that phonological representations may be of particular importance in syntactic operations. The consequences of a phonological coding deficit might therefore be specific to syntactic operations, leaving the semantic aspects of sentence processing intact. This provides a vantage point for our investigation of E.A. The major questions to be addressed in this case study are first whether E.A. demonstrated selective difficulties in the use of syntactic information, and second whether any observed syntactic deficits were due to loss of the knowledge of language structure or may be attributed to the phonological memory deficit. To the extent that observed syntactic difficulties can be attributed to the memory deficit, the pattern of E.A.'s performance will allow us to make inferences about the role of phonological memory in normal sentence comprehension.

Neuropsychological Issues.

The link between phonological coding and sentence processing is important in the context of the existing aphasia literature as

well. In their review of the literature, Caramazza and Berndt (1978) suggested that lexical, syntactic and semantic heuristic language processes are independent components of the overall comprehension process and may be selectively impaired depending upon lesion location. The general characterization that has emerged is that with left posterior lesions the ability to extract the meaning of individual lexical items is impaired while the ability to generate a variety of appropriate syntactic constructions remains intact; in contrast, an anterior lesion may result in a severe limitation in syntactic processing abilities that is apparent in both production and comprehension of sentences. These anterior patients, particularly those with telegraphic productions, appear to have a basic deficit in the knowledge or use of syntactic information that extends to all arenas of language.

While the anterior-posterior distinction is consistent with a good deal of research on aphasic syndromes, there are other findings that do not fit so easily into the syntax-semantics dichotomy. Recent evidence suggests that anterior aphasics may show some preserved syntactic abilities (Micheli, Mazzucchi, Menn & Goodglass, 1983); conversely, posterior aphasics have been shown to have syntactic impairments. Specifically, although conduction aphasia results from posterior lesions, these patients demonstrate a comprehension deficit comparable to that of Broca's (anterior) patients (Caramazza & Zurif, 1976; Heilman & Scholes, 1976; Scholes, 1978; Caramazza et al., 1981, Rothi, MacFarling, & Heilman, 1982). Accurate comprehension of syntactically complex sentences appears to depend upon the ability to extract a semant-

ically plausible interpretation of the major lexical items for both Broca's and conduction aphasics (Caramazza & Zurif, 1976). Both groups showed good comprehension in a picture- selection task when the sentence contained semantic constraints (e.g., The dress that the woman is washing is torn), but tended to make noun phrase reversal errors on sentences that were unconstrained (e.g., The cow that the monkey is scaring is yellow) or semantically improbable (e.g., The man that the horse is riding is fat). Caramazza & Zurif concluded that although comprehension based on a purely syntactic analysis was impaired, these patients retained their ability to use heuristic devises (such as a strategy of semantic plausibility) in sentence interpretation.

Although anterior aphasics and conduction aphasics show a similar comprehension deficit in syntactic analysis, the source of the dysfunction may not be the same for the two groups. In fact, the nature or extent of the syntactic disorder in conduction aphasia has rarely been investigated in a systematic way. However, in a case study of a conduction aphasic, M.C., that did provide a broad analysis of linguistic abilities, Caramazza et al. (1981) demonstrated a major dissociation between an impaired ability to understand syntactic information and an intact ability to produce grammatically correct sentences. M.C.'s oral reading, spontaneous speech and productions in a sentence anagram test were grammatically well-formed, unlike the productions of agrammatic patients. M.C.'s performance on a story completion test was also good in that he most often produced grammatically well-formed utterances, although he did have some difficulty in pro-

ducing constructions most appropriate to a given context. It is not clear, however, whether this difficulty resulted from poor comprehension of the stories or from an inability to produce certain types of grammatical constructions. Despite the difficulties in production noted on the story completion task, Caramazza et al. felt that the discrepancy between production and comprehension was so great that the comprehension deficit should be attributed to a short term memory deficit rather than a syntactic deficit (a conclusion made plausible by the patient's extremely restricted memory span). That is, M.C.'s comprehension errors were not the result of a general impairment in syntactic processing but were due to a inability to retain information from one part of a sentence while another part was being processed.

Evidence that a deficit in phonological short term storage may not effect sentence production is provided by Shallice & Butterworth (1977). They found little difference between their patient and a group of normal controls in the number of hesitations, pauses or grammatical errors in near-spontaneous speech. However, this patient's memory span was not as severely restricted as that of M.C. or E.A. Additionally, these researchers did not attempt to elicit specific types of grammatical constructions from the patient and it therefore remains possible that the patient would have shown difficulties in the production of syntactic forms that draw heavily on a phonological memory system.

Additional broad-based analyses are clearly needed in order identify the nature of semantic and syntactic processes in conduction aphasia. In this study, we investigated E.A.'s sentence

processing ability in tests of comprehension, production and repetition. The comprehension tests were designed to replicate earlier analyses of sentence comprehension and to separate the roles of prepositions and word order in signalling syntactic structure. The purpose of the production tests was to evaluate E.A.'s ability to generate different sentence constructions and her sensitivity to the contextual constraints that define what constructions are appropriate. Finally, the sentence repetition data should provide insight into the strategies that E.A. used in attempting to process complex syntactic constructions.

CASE HISTORY

A brief history and clinical profile of E.A. will be presented here; more detailed information can be found in Friedrich, Glenn & Marin (1984). E.A., a college educated woman, suffered a left- sided stroke in October, 1975; a recent CT scan (7/82) revealed a large lesion involving the posterior temporal and superior and inferior parietal areas. She had a severe impairment of repetition ability, as reflected by an auditory digit span of 1.5 and a visual span of 2.4. Repetition of letters and lists of unrelated words was comparable to digit span, but repetition of nonsense syllables was more impaired in that she was frequently unable to repeat even a single item correctly.

In casual conversation, E.A.'s expressive and receptive language capabilities appeared to be quite good. Spontaneous speech was fluent, prosodic and grammatical, but was marked by occasional word-finding difficulties and phonemic paraphasias.

Her average rate of speech was 150-160 words/minute.

Auditory comprehension as measured by the Token test was 75%, reflecting difficulty in carrying out long or syntactically complex instructions. In a test of reading comprehension (Gates-McGinitie Test) she scored in the 38th percentile, although she performed in the 97th percentile in the vocabulary section. E.A. reported that reading was difficult because she was slow and tended to forget the first part of a sentence by the time she reached the end. Oral reading of single words was slow but generally accurate. There was no evidence of a word class distinction: accuracy was comparable for lists of function words (38/39 correct) and content words (36/39) that were matched for frequency. In oral reading of text, however, she showed a marked tendency to omit function words and verb inflections.

COMPREHENSION

The primary emphasis in the evaluation of comprehension in conduction aphasia thus far has been on the effects of semantic constraints in sentence comprehension. Conduction aphasics, like Broca's aphasics, make frequent subject-object reversal errors for sentences that are unconstrained and where comprehension is dependent upon syntactic analysis (e.g., The boy that the girl is chasing is tall) but rarely make errors on semantically constrained sentences (e.g., The wagon that the horse is pulling is green; Caramazza et al., 1981; Caramazza & Zurif, 1976, see also Vallar & Baddeley, 1984b). The fact that these two groups of patients are comparable in their abilities to use semantic but not

syntactic information should not imply that the source of the syntactic deficit is the same in both cases, however. There are at least two types of impairment that could produce the pattern of comprehension deficit found in Broca's and conduction aphasics.

(1) This pattern could reflect a general loss in the knowledge or use of syntactic structures. There is little agreement in the literature as to what level of syntactic knowledge is lost. The "function word theories" (Caplan, 1983) have focused on a specific impairment in the use of function words and grammatical morphemes (Bradley, Garrett & Zurif, 1980; Kean, 1977,1982; Caplan, 1983). Schwartz, Saffran & Marin (1980), on the other hand, have argued that the syntactic deficit goes beyond a failure to exploit the syntactic information carried by function words and consists of an inability to map thematic information onto the constituent word order of a sentence. In English, word order provides important structural information that is not dependent upon grammatical morphemes, in that a noun-verb-noun sequence generally maps onto a subject-verb- object construction. Schwartz et al.'s study indicated that their agrammatic patients were not making use of these probabilities of language structure, as reflected by their high error rates on active reversible sentences (e.g., The car hits the ball) for which the S-V-O mapping strategy would lead to accurate comprehension.

(2) The syntactic comprehension deficit could also be the result of a short term memory impairment. Caramazza et al. (1981), for instance, argued that M.C.'s use of syntactic infor-

mation in production tasks demonstrated that his knowledge of syntax was generally intact. They suggested that a reduced memory capacity made it difficult for M.C. to retain the results of syntactic analysis extracted from different parts of the sentence. As a consequence, sentence interpretation was based on the semantic information derived from the major lexical items.

The nature of the comprehension deficit in conduction aphasia has not been investigated sufficiently to discriminate between these alternative accounts. In particular, the ability of the conduction aphasic to use the probabilities of language structure (such as S-V-O mapping) has not been evaluated. In the present study, we evaluated E.A.'s use of syntactic information signaled by grammatical morphemes and word order and her comprehension of spatial prepositions. In all cases the task consisted of selecting the picture that matched the presented sentence from a set of two pictures, one displayed above the other.

Task 1: Comprehension of reversible active and passive sentences.

Two sets of materials were used, one drawn from Schwartz et al., (1980) and one developed by the second author. The first set was presented twice (in different testing sessions) and reversed role distractors occurred on every trial; the second set was presented once and contained lexical as well as reversed role distractors. Examples of the materials are presented in Table 1. In both the auditory and visual conditions the sentences were presented as E.A. viewed the pictures in order to minimize the memory demands of the task. E.A. responded by pointing to one of

the two pictures.

Insert Tables 1 & 2 about here

E.A.'s performance (see Table 2) was consistent with other reports in that lexical errors were very rare (3% errors overall). On the reversed role distractor trials, E.A. made significantly more errors of subject-object reversal on the passive sentences than on the active sentences in both the auditory ($z = 2.13$, $p<.03$) and visual ($z = 2.17$, $p<.03$) conditions. The fact that E.A. made very few errors on the active sentences (5% overall) indicates that, unlike Schwartz et al.'s (1980) agrammatic patients, E.A. was able to use word order information to arrive at an appropriate interpretation of reversible active sentences. In the passive sentences the usual N-V-N to S-V-O mapping is violated and the passive construction is marked by the passive verb form ("was hit") and the preposition "by". Although E.A.'s performance was above chance, her errors were consistent across testing sessions and suggest a marked tendency to process the sentence on the basis of an S-V-O interpretation without regard to the presence of grammatical morphemes. Her improvement under conditions of visual presentation indicates that when she was able to process the sentence at her own rate and for an unlimited time she was able to use these morphemes, although the syntactic information provided by those markers was still somewhat vulnerable to significant disruption.

Task 2: Comprehension of spatial prepositions.

In order to get another assessment of E.A.'s ability to ex-

tract relational information signaled by prepositions, we tested E.A.'s comprehension of locative sentences (e.g., The circle is above the square). Again, two sets of materials were used in several testing sessions; one, based on Schwartz et al. (1980; Exp. 3), used only reversed role distractors and included action verbs as well as locative sentences; the second set included only locative sentences but used both lexical and preposition distractors. Examples are provided in Table 1.

All of E.A.'s errors on this task were made on trials using a reversed role distractor; E.A. never made the error of selecting a picture in which a different object or spatial relation was introduced. Moreover, E.A. made significantly more errors on the locative sentences than on the transitive verb sentences in both the auditory and visual conditions ($z = 2.64$, $p<.001$ and $z = 2.22$, $p<.02$, respectively). The fact that she didn't make errors with lexical or prepositional distractors indicates that she was able to extract the appropriate semantic features of the prepositions; however, compared to sentences containing transitive verbs the comprehension of sentences in which the relational information was carried by prepositions was clearly more difficult. As with the reversible passive sentences, E.A.'s performance was better with visual than with auditory presentation, although she did produce a consistent and significant pattern of errors even in the visual condition.

Summary of comprehension data.

The results of Tasks 1 and 2 demonstrate that E.A.'s comprehension of passive reversible and locative sentences was

impaired, particularly with auditory presentation of the stimuli. An important finding is that E.A. made few errors for active sentences with reversed role distractors; thus, the nature of her asyntactic comprehension differed from that of Schwartz et al.'s (1980) agrammatic aphasics in that she appeared to use word order probabilities to interpret reversible sentences. When word order violated the usual S-V-O mapping or the relational information was carried by spatial prepositions, however, role reversal errors were frequent.

The contrast in performance between active and passive reversible sentences indicates that E.A. did not have a general syntactic deficit in mapping thematic information onto constituent word order. Her ability to use word order information to assign grammatical roles and her improvement in performance under visual conditions suggest that E.A. was not generally impaired in processing syntactic information. In fact, E.A. showed the pattern of performance that Schwartz et al. (1980) predicted would result from a phonological coding impairment, based on the assumption that grammatical morphemes are dependent upon a phonological representation.

It is difficult to separate the effects of a selective impairment of phonological coding from a more general short term memory deficit that prevents the retention of "local" syntactic analysis (see Caramazza et al. 1981). On the basis of E.A.'s results, however, we can define more clearly some constraints on the nature of the STM impairment. First, different types of information held in memory are not equally vulnerable to loss;

across all four tasks, only one lexical error occurred. Thus, the semantic values of the nouns and verbs are stable in memory while structural and relational information is highly vulnerable. Second, memory load can not be completely defined in terms of sentence length, or even in terms of the number of "idea units" within a sentence. The reversible locative sentences were equal in length and number of relations to the transitive verb sentences but produced many more role reversal errors; this suggests that the type of relational information carried by spatial prepositions may be more dependent upon a phonological representation and is thus more vulnerable to loss even though memory capacity for semantic information has not been exceeded.

PRODUCTION

The identification of a central syntactic impairment appears to rest to a large degree on the extent to which syntactic errors occur in all arenas of language, i.e., visual and auditory comprehension, oral and written expression, and linguistic intuitions (Caramazza et al., 1981). In a case such as E.A., in which there is evidence of a comprehension deficit for syntactically complex materials, an analysis of sentence production is particularly important in order to determine whether a general syntactic impairment exists.

E.A.'s spontaneous speech was quite fluent and demonstrated appropriate use of prepositional phrases, specificity of noun phrases, and generally well-formed sentences. Several features stood in sharp contrast to a classically agrammatic production:

articles, functors and verb inflections were present, negative (e.g., "that really didn't help") and question (e.g., "what do you call it") constructions were were appropriate, and the rate of speech and prosody indicate that articulation was not effortful. However, such samples are not particularly revealing in terms of E.A.'s ability to handle a variety of sentence constructions; as is typical in spontaneous speech, her sentences were relatively short and simple.

Spontaneous written productions were more difficult for E.A.; she reported that, in addition to poor spelling, she had difficulty constructing and organizing sentences that were complete and made sense. When asked to write a paragraph on a particular topic, she worked slowly but did produce an informative paragraph consisting of 10 sentences and a total of 110 words. In addition to several spelling errors and a few potential word choice errors, there were 12 unambiguous grammatical errors in this sample. Half of these involved verb omission or tense agreement errors, and there were three errors in which pluralization was omitted. Although she was able to produce appropriate future and passive constructions on some occasions ("It will be the first time..."; "Each duo will be graded..."), she made errors on similar constructions at other points (e.g., "We see 3..."; "The winner will judges...").

E.A. clearly demonstrated an ability to use a number of different sentence constructions in her spontaneous productions; in order to evaluate this ability under more constrained conditions we administered story completion and picture description tasks

requiring both oral and written responses.

Task 3: Story completion.

Two sets of story fragments were presented aurally to E.A. One consisted of materials which were designed to elicit 14 different sentence constructions (Goodglass, Gleason, Bernholtz & Hyde, 1972); the other focused on active and passive constructions only. In one session E.A. made oral responses and in another session she made written responses to the same materials. All of the 28 oral responses to the Goodglass material were grammatically correct; 16/28 responses conformed to the target sentence form. Her responses matched the conventional responses identified by Goodglass et al. for imperatives, transitive and intransitive declaratives, yes/no and WH- questions, and sentences using cardinal numbers. In contrast, she failed to generate passives,embedded clauses, comparatives and adjective-adjective- noun combinations in the appropriate contexts and was inconsistent in her use of the future construction.

The second set of materials focused exclusively on active and passive constructions: in all cases E.A. produced the appropriate sentence form, although 3/4 passives were truncated. The fact that she produced passive forms appropriately here is an indication that she was sensitive to contextual cues (in this case, which noun phrase was the focus of the sentence) and could construct them correctly.

Of the written responses to the Goodglass material, 19/28 followed the conventional form. Her ability to produce certain sentence types was better in the written version, as she produced

the comparative forms appropriately and produced one correct example of both the passive and embedded constructions. Even when E.A.'s responses did not match the conventional form, they were generally well-formed and complete sentences. Overall, however, her written productions were marked by many errors in spelling and in the use of inflectional suffixes. There were seven errors in verb form, three involving tense and four number agreement. In addition, pluralization was omitted from both sentences requiring cardinal numbers. Thus the pattern of errors is highly consistent with E.A.'s performance in spontaneous writing both in the type of sentence constructions that were difficult and in the omission of grammatical morphemes.

In the active/passive stimulus set, E.A. again demonstrated her sensitivity to the intended focus of the sentence; she correctly generated all four actives and 3/4 passive constructions, although two of the passives were produced in truncated form.

Task 4: Picture description.

In this task, E.A. looked at a picture of an action scene and was asked a question designed to elicit either an active or passive construction in response. For a picture of a truck pulling a car, for instance, the active form question would be "what did the truck do?" and the passive form would be "what happened to the car?".

In her oral responses, E.A. consistently produced both active and passive forms in the appropriate contexts. The passives were somewhat variable in terms of how closely they matched the

target constructions: 4/8 were conventional passives and 2 were ungrammatical due to an inappropriate sequencing of prepositional phrases (e.g., 'The ball is being hit by a stick by a boy'). The two other passive responses were correct in both meaning and structure, but they differed from the target construction in that the main clause of the sentence was actually in active form while the passive segment described the action of a person on an inanimate object. Thus, the target of "The boy was pulled by the girl" was elaborated by E.A. into "The boy is riding in a wagon pulled by a girl". For the dative constructions, E.A. generated complete dative forms for the two active trials but produced truncated forms for the passives.

E.A.'s inconsistent use of the passive form was more apparent in her written responses. Only 3/8 of the passives were correct and in the target form. On three of the incorrect trials, she responded with an active construction; in addition, she used the active voice for both of the passive dative trials. On one passive trial, she did use passive voice but selected a verb that did not match the subsequent prepositional phrase ("The girl was afraid by a mouse"). Moreover, in the task as a whole E.A. made 6 errors of verb form, most often omitting the auxiliary verb in her use of the present progressive.

Summary of the production data.

The results of the story completion and picture description tasks demonstrate clearly that E.A. was sensitive to contextual cues and capable of generating a variety of appropriate grammatical structures. Moreover, even when her productions did not

match the target form, as was often the case for passive constructions, she did map the underlying semantic relations onto an appropriate surface structure accurately. E.A.'s errors on trials eliciting passive constructions were not the result of an incorrect assignment of a noun phrase to a grammatical role; instead, she made the correct subject/object assignments and constructed sentences in active voice. In the case of passives, then, the bias toward the S-V-O word order sometimes overrode the contextual cues indicating that the object should be the focus of the sentence, particularly when written responses were required.

It is also with the written materials that E.A.'s errors in using grammatical morphemes emerged: in spontaneous writing, story completions and picture descriptions, E.A. consistently omitted auxiliary verbs and made errors in number and tense agreement. However, this sort of error rarely if ever occurred in spontaneous speech or in oral responses to the story completion and picture description tasks. This suggests that grammatical markers were represented in E.A.'s internal syntactic constructions but were especially vulnerable to loss during the translation of the phonological representation to a written form.

SENTENCE REPETITION

The sentence repetition task provides a particularly interesting measure of semantic and syntactic operations in language processing. On one hand, it may be treated as a highly constrained production task, since the oral production can be strictly evaluated in terms of how well it matches the stimulus

sentences. Thus, difficulties in producing specific syntactic forms can be more readily identified and quantified than in spontaneous production tasks. Moreover, both the semantic relations and the sentence form of the production are constrained and can be evaluated separately.

On the other hand, repetition has often been used as a measure of comprehension, particularly in studies of language acquisition. Errors in repetition may reveal not only the types of constructions that are difficult to understand, but also the strategies that are used to decode the stimulus sentence. Such strategies are more difficult to identify in a picture- selection comprehension task, since the type of error made is determined by the type of distractor that is presented. Saffran & Marin (1975) used repetition as a means of evaluating sentence comprehension in a patient with a short term memory deficit. They noted that I.L. often preserved the meaning of passive sentences but repeated them in the active voice, indicating that the semantic relations were accurately extracted but that the surface form of these relations was not preserved.

There are two strategies that may play an important role in E.A.'s language processing. On the basis of E.A.'s performance on the active/passive comprehension tests, it appears that she frequently made use of the S-V-O strategy in assigning grammatical roles. That is, when the subject and object of a sentence were semantically reversible, E.A. treated the first noun as the agent of the sentence, resulting in a high error rate on passive sentences.

Another comprehension strategy that has been identified in conduction aphasics is the use of a semantic heuristic, as described by Caramazza & Zurif (1976). Even when the S-V-O ordering is violated, both Broca's and conduction aphasics showed accurate comprehension if the subject-object relationship was constrained by semantic factors. Clearly, a semantic strategy took precedence over a word order strategy in such conditions.

E.A. participated in two sentence repetition tasks. The first set of materials included active and passive reversible sentences; this provides a rough measure of comparability between the comprehension and repetition tasks as well as an indication of E.A's sensitivity to semantic and syntactic aspects of the sentences. The second set of materials consisted of sentences with relative clauses. These sentences were derived from the comprehension materials used by Caramazza & Zurif (1976) in which the degree of semantic constraint within a sentence was manipulated.

Task 5: Repetition of active and passive sentences.

The materials consisted of a set of 10 active reversible sentences employing transitive verbs and 10 passive versions of the same sentences. The two sentence types were presented randomly to E.A. who was asked to repeat them verbatim.

Of the 10 active sentences, E.A. produced all 10 in active voice, although only 4 were verbatim repetitions. In 4/6 of her incorrect repetitions, the semantic relations were retained but the specific wording of the repetition differed from the original, including one lexical substitution ("policeman" for "cop")

and 4 verb form changes (e.g., "is kicking" for "kicks"). The other two incorrect repetitions involved subject-object reversals in which the meaning of the original sentence was violated (e.g., "The cat chases the dog" was repeated as "The dog chases the cat").

Of the passive sentences 3/10 were exact repetitions, but 5/10 repetitions violated the meaning of the stimulus sentence via subject- object reversal errors. Moreover, four of these five responses were in active voice, so that the original word order was retained but the surface form of the repetition was altered (e.g., "The man is drawn by the woman" was repeated as "The man is drawing the woman"). In addition, there were 7 verb form changes, one lexical substitution, and one word omission.

E.A.'s performance on both the active and passive was very good in terms of retaining the meanings of the major lexical items; that is, she provided the correct nouns and verbs. E.A. retained the order of the major constituents very well for both the active and passive versions of the sentences; the order of the nouns matched the stimulus sentence in 8/10 of the active and 9/10 of the passive trials. In addition, E.A. appeared to use word order as a means of assigning the roles of agent and object, such that the first noun was incorrectly treated as the agent in 4/10 of the passive sentences. These results are consistent with E.A.'s comprehension data, in which her errors on passive reversible sentences took the form of subject-object reversals and suggest that the grammatical markers signaling passive voice were not reliably extracted from the stimulus sentence.

Task 6: Repetition of relative clause sentences.

Sentences using relative clauses can be constructed in a variety of ways to tease apart factors affecting syntactic complexity. One factor concerns the location of the relative clause: in the center- embedded sentence, the relative clause interrupts the main clause (e.g., "The boy that is eating the apple is tall") while in the right-branching sentence the main clause remains intact (e.g., "The boy is eating the apple that is red"). Evidence that adults have difficulty processing multiply-embedded sentences is attributed to the increased memory demands of the embedded form (Miller, 1962); essentially, the first part of the main clause must be maintained in memory until the clause is completed at the end of the sentence.

The second factor in syntactic complexity is the role that the noun modified by the clause plays; this defines the focus of the clause. For subject focus sentences, the head noun serves as the subject of the relative clause (e.g., "The boy that is eating the apple is tall") and an S-V-O ordering of the constituents is retained. When the head noun is the object of the relative clause, in the object focus sentences, the S-V-O ordering is violated (e.g., "The apple that the boy is eating is red"). The factors of embeddedness and focus can be varied independently, creating four sentence types.

In their demonstration of the aphasics' use of heuristic strategies based on semantic constraints, Caramazza & Zurif (1976) used relative clause sentences that were both embedded and had an object focus. In order to evaluate the interaction of se-

mantic processing in complex sentences, we constructed a set of materials in which semantic constraints were varied for all four types of relative clause sentences. This allowed us to separate the effects of memory load and of the S-V-O mapping strategy from the use of a semantic strategy. Examples of the 12 resulting sentence types are provided in Table 3.

Insert Table 3 about here

Eight sentences of each of the 12 sentence types were randomly presented over several testing sessions. In order to identify E.A's retention of both semantic and syntactic information, we employed an analysis similar to that used by de Villiers et al. (1979). First, the three relations within each sentence type were identified: subject-verb, verb-object, and noun-adjective. Each sentence was analyzed to determine which of these links were retained in the repetition, regardless of the surface structure of the sentence. For instance, E.A.'s repetition of "The apple that the boy is eating is red" was "The boy was eating the apple that was red". Although the surface form of the repetition was incorrect, her identification of the relations between the nouns, verbs and adjective were correct, and she received one point for each of the three possible links (e.g., boy-eat; eat-apple; apple-red). In contrast, her response to "The wagon that the horse pulled was green" was "The horse that pulled the wagon was green". In this case, the subject- verb (horse-pulled), and verb-object (pulled-wagon) links each received a point, but the adjective link (wagon- green) did not. The proportion of links

retained (out of a possible 24) was computed across the eight sentences of each type. This provides an indication of the degree to which the relations between words were correctly extracted, regardless of the surface form of the repetition.

The frequency of lexical substitutions presents somewhat of a problem for this type of analysis: E.A. sometimes used synonyms or semantically similar words instead of verbatim repetition. Two scoring criteria were used to reflect these changes without obscuring the relations that were intact. In the strict criteria credit was given only when the exact word was used in repetition, with the exception of tense which E.A. habitually altered. Under the lenient criteria, semantically similar items were given credit, unless they had occurred elsewhere in the original sentence. Thus, "holding" was treated as an acceptable substitute for "carrying" and "tall" for "skinny", etc. The results of both criteria are presented in Table 4, which shows the results of the semantic analysis of E.A.'s repetitions.

Insert Tables 4 & 5 about here

A second type of analysis was carried out in order to determine the extent to which E.A. retained the structural features of the stimulus sentence, regardless of the semantic accuracy. For each sentence type, the number of subject vs. object focus productions and the number of center-embedded vs right-branching productions were computed. Results are presented in Table 5.

Overall, the semantic constraints of the stimulus sentence played an important role in E.A.'s ability to retain the correct

semantic relations in her repetitions. Across the four different sentence types, 81% of the semantic links were preserved for the irreversible sentences compared to 54% for the reversible sentences and 34% for the improbable sentences. The semantic heuristic strategy clearly played an important role here, even to the extent that E.A. would "correct" the improbable sentences in order to make them more plausible. However, the syntactic form of the input sentence also had an important impact on the retention of semantic relations in E.A.'s repetitions for both the irreversible and reversible sentence types.

Semantically Irreversible Sentences

For the irreversible sentences, E. A. could guess at the intended meaning of the sentences on the basis of semantic plausibility. However, even if she were to understand the sentences on this basis, this would not guarantee that her repetitions would match the surface form of the target. For example, for the target sentence of "The boy is eating the apple that is red," the only plausible interpretation is that the boy is eating the apple (not vice versa) and that the apple (not the boy) is red. However, E.A.'s production could differ from the target and still express the same relationships. She might say "The boy is eating the apple and the apple is red," or "The boy is eating a red apple." Given that it is extremely unlikely that E. A. could repeat the sentences accurately on the basis of rote memory, the extent to which E. A.'s productions match the targets in form is an indication of her ability to note the syntactic construction

of the target and use this form in production.

For the irreversible sentences, the semantic relations were better preserved for the subject focus (96%) than for the object focus sentences (66%; see Table 4). For the subject focus sentences, not only were semantic relations preserved, with correct grammatical role assignments in all cases, but E.A. repeated all 16 sentences using the surface structure of the original (see Table 5). In other words, right-branching structures were repeated as right-branching structures and embedded structures were repeated as embedded structures. The only exceptions to verbatim repetitions were a few verb tense and lexical substitution errors. This pattern is an indication of a good deal of preserved syntactic ability since these sentences were quite complex.

The picture was quite different, however, for the object focus sentences. Although these sentences do not adhere to the S-V-O ordering of constituents, E.A. assigned grammatical roles correctly (i.e., first noun = object, second noun = agent) in all cases for the right- branching sentences and 88% of the time for the center-embedded sentences, and her retention of semantic information overall was good. However, the surface form of the sentence was altered on 13/16 repetitions. As indicated in Table 5, a subject focus construction was used in 12 of the incorrect repetitions. For the right-branching sentences (e.g., "The bicycle is broken <u>that the boy is holding</u> "), she changed the main clause into a relative clause (e.g. "The bicycle <u>that is broken,</u> the boy is holding") on five of the eight sentences. On 7/8 center-embedded sentences, E.A. produced subject focus sentences

by using the subject of the relative clause as the main subject of the sentence. On three trials this resulted in transforming a center-embedded form into a right-branching form that correctly expressed the semantic relationships in the target (e.g., "The apple that the boy is eating is red" was repeated as "The boy is eating a apple that is red "). On the other four trials, however, she retained the center-embedded form and as a result assigned the adjective to the incorrect noun (e.g., "The wagon that the horse is pulling is green" was repeated as "The horse that is pulling the wagon is green"). It should be noted that there was no way to produce a subject focus center-embedded form that would correctly express the semantic relationships in the original. E.A.'s attempt to use this form may have resulted from her recognition that there was a center-embedded clause in the target, although she demonstrated a lack of awareness that she has inappropriately linked the adjective to the head noun. This lack of coordination in the use of the use of subject focus and embeddedness structures accounts for E.A.'s reduced performance in the semantic analysis of these sentences (Table 4).

Semantically Reversible Sentences

For these sentences, comprehension of relationships could not be made on the basis of semantic plausibility; both the assignment of agent and object roles and the decision as to which noun was modified by the adjective could only be determined on the basis of the syntactic form of the sentence. A comparison of E.A.'s performance on the reversible and non-reversible sentences

should thus reveal the role of the semantic heuristic in her comprehension.

For the subject focus sentences, E.A. again did very well on the right-branching forms, producing 7/8 verbatim and correct agent-object role assignments in all 8 sentences. E.A. had somewhat more difficulty with the center-embedded subject focus sentences; only 4/8 were repeated verbatim, one sentence was not repeated at all and in one the roles of agent and object were reversed in her production. For 5/6 sentences that preserved role relations, E.A. used the surface form that was given in the target. Overall then, these results indicate a fair ability to understand and use the center-embedded form even though a semantic heuristic could not be used. The somewhat worse performance on these embedded sentences compared to the right-branching form possibly reflects the additional processing load produced by the interruption of the main clause.

For the object focus sentences, E.A. had trouble even with the right-branching sentences. Her productions generally preserved the adjective-noun link but were incorrect in the agent-object role assignment. In 6/8 sentences, these roles were reversed as these object focus sentences were transformed into subject focus sentences with the first noun serving as agent rather than object of the transitive verb. It is interesting to note that on five of these six trials, E.A. inappropriately produced center-embedded forms, (e.g., "The horse is brown <u>that the bear is kicking</u>" was repeated as "The horse <u>that is brown</u> is kicking the bear").

For the center-embedded object focus targets, E.A. reversed the roles of agent and object on the 5/8 sentences and produced a right-branching form that assigned the adjective to the wrong noun. (For example, for the sentence "The fish that the frog is biting is green", E.A. produced "The fish is biting the frog that is green "). Like the pattern shown in the irreversible sentences, she showed a preference for producing an S-V-O form, but unlike the irreversible case where semantic constraints identified the likely the subject, in the reversible case she tended to use the first noun.

Semantically Improbable Sentences

The improbable sentences were designed to pit syntactic analysis against semantic plausibility; that is, accurate comprehension of these sentences required the use of a syntactic analysis and the rejection of a semantic heuristic. It is conceivable that this type of sentence would also be somewhat difficult for intact adults to repeat, although Caramazza & Zurif's (1976) control subjects had no difficulty with complex improbable sentences in a comprehension task. In these sentences the subject- object relation was improbable although the adjective link made sense (e.g., "The man that the horse is riding is fat"); accordingly, the noun-adjective link was most often retained in E.A.'s repetitions.

E.A. frequently reversed the subject-object roles, creating more semantically plausible sentences (e.g., "The man that is riding the horse is fat"). Correct role assignment

occurred only 32% of the time across all sentence types. This tendency to make semantic "corrections" was apparent for all sentence types, although E.A. did produce five correct repetitions (except for lexical substitutions), of the subject focus sentences, compared with two correct repetitions of the object focus sentences.

E.A. correctly repeated three right-branching subject focus sentences, assigned roles incorrectly on three sentences and left the remaining sentences incomplete. Of the center-embedded subject focus sentences, E.A. repeated two correctly and produced only the first noun on another. In four of the five remaining sentences she reversed the agent and object roles.

The variability of E.A.'s repetitions of the subject focus sentences and the nature of the resulting errors suggest some effort to reconcile the conflict between the syntactic analysis and semantic plausibility. This finding is consistent with E.A.'s relatively accurate syntactic analysis of the irreversible and reversible subject focus sentences. The syntactic analysis of the object focus sentences from the irreversible and reversible groups was less reliable, however; thus, we might expect E.A. to be more dependent upon semantic plausibility in interpreting object focus constructions. Her repetition performance for improbable object focus sentences did in fact reveal a consistent tendency to make the sentences plausible. Only one of the right-branching object focus sentences was repeated correctly and the agent-object assignment was reversed on 63% of the trials. For the object focus center-embedded sentences, one sentence was pro-

duced verbatim and 6/8 repetitions reversed the role of agent and object. Across all the improbable object focus sentences, 11/16 were repeated as subject focus sentences, again demonstrating a bias toward using the S-V-O construction.

Summary of Repetition Data

The reversible sentence has often been used in conjunction with a picture selection task to test aphasic's syntactic comprehension abilities. As Saffran and Marin (1975) and others have suggested, sentence repetition can also provide a measure of syntactic comprehension, particularly for a patient like E.A. whose memory limitation makes it extremely unlikely that a complex sentence could be accurately repeated on the basis of rote recall. This notion is strongly supported by E.A.'s repetition of active and passive sentences (Task 5), which corresponds very well to her performance on the active/passive comprehension tests (Task 1). In both cases, in the absence of semantic constraints E.A. frequently treated the first noun in the sentence as the agent and the second as the object, producing subject-object role reversals in the passive sentences.

Repetition of the relative clause materials, in which semantic constraints, clause location and agent/object order within the sentence were varied independently, provides information about E.A.'s syntactic capabilities and processing strategies that is not available from the comprehension data. The semantic analysis reveals a systematic decline in performance as the sentences increase in processing complexity. Embeddedness, for instance, had virtually no effect on the irreversible subject focus

sentences, but produced a considerable effect when semantic constraints were removed and the gist of the sentence could not be maintained on the basis of semantic plausibility. Similarly, performance on the object focus constructions was somewhat impaired relative to the subject focus sentences even in the irreversible condition, but this effect was considerably amplified in the reversible condition. Thus, a picture develops of the interaction of semantic and structural elements in sentence processing and how the presence or absence of one element altered E.A.'s ability to process other elements.

In addition, the results demonstrate a remarkably intact ability to understand and produce complex constructions under certain conditions. It is clear, for instance, that although E.A. made grammatical role assignments on the basis of semantic plausibility whenever possible, she also made use of word order and surface form information. E.A. produced the irreversible subject focus sentences in a grammatically correct form, and more importantly, she used the complex relative clause forms in which the targets were given. When semantic constraints were not available, in the reversible sentences, both the meaning and the structure of the subject focus forms were still retained well. However, the increased difficulty of the processing, due to the lack of semantic constraints, was reflected in the fact that embeddedness had an effect.

When use of semantic constraints and the S-V-O mapping strategy were set in opposition to one another, as in the irreversible object focus sentences, the semantic strategy determined the

assignment of agent/object roles, but there was a definite cost in terms of both the semantic and structural elements of the repetition. E.A.'s recognition of and attempts to reproduce certain structural features under these conditions was evident; for instance, she did produce a sentence form that placed the object of the main clause before the subject and verb (e.g., "The coat that was torn , the girl was wearing") and she frequently used a center-embedded form, sometimes inappropriately. There was little evidence that she could coordinate use of these structures simultaneously, however. And when neither the semantic nor the S-V-O strategy were appropriate, as in the reversible object focus sentences, E.A. was generally inaccurate in her role assignments and retention of surface form.

A plausible argument can be made that the object focus sentences do place greater demands on phonological memory than the subject focus sentences (see, for example, Wanner and Maratsos, 1978). Normal subjects have been shown to use a strategy of assuming that the first noun encountered in a sentence is the subject of the sentence (Bever, 1970). In the subject focus sentence, this assumption is confirmed by the subsequent structure of the sentence. For the object focus sentence, this assumption is not confirmed and in fact the role of the first noun with respect to the verb cannot be determined until after the verb. In the comprehension of such sentences a phonological representation of the ambiguous material may be necessary until role relations can be assigned.

GENERAL DISCUSSION

The data from the comprehension, production and repetition tasks presented here serve two purposes. First, we have attempted to develop a rich profile of the language processing capabilities of a patient with a phonological coding impairment and to clarify the differences in performance between this sort of impairment and other aphasic disorders. Second, by studying a patient whose ability to maintain phonological information in memory was limited, we can come to a clearer understanding of the role that the phonological code plays in complex language processing.

E.A.'s performance was generally consistent with the reports of other conduction aphasics on sentence processing tasks (Saffran & Marin, 1975; Shallice & Butterworth, 1977; Caramazza et al., 1981; Vallar & Baddeley, 1984b). The evidence of "asyntactic" comprehension by these patients has received the most attention, since the pattern of errors is the same as that of anterior aphasics who have a syntactic processing deficit for both comprehension and production. It has been argued previously that the comprehension deficit in conduction aphasia is a result of impaired short term memory rather than impaired syntactic processes (Caramazza et al., 1981; Vallar & Baddeley, 1984b). The possibility remains, however, that syntactic operations for comprehension and production are independent and can be dissociated; Micheli et al.'s (1983) report of two patients with agrammatic production but apparently normal comprehension supports this notion. Thus, conduction aphasics in general and E.A. in

particular could have a specific syntax comprehension disorder in addition to the phonological memory deficit.

Vallar & Baddeley (1984b) presented evidence that makes the specific syntactic impairment account unlikely. Their patient, P.V., showed normal comprehension of syntactically complex constructions in sentences that were 5-9 words in length, but made frequent comprehension errors on similar sentences that were 13-22 words in length. Thus, P.V.'s syntactic analysis processes per se appeared to be intact, even though performance broke down as task difficulty increased.

It is important to note that P.V. was clearly different from E.A. and other conduction aphasics in that her performance on an active/passive picture selection test, similar to our Task 1, was quite good. It is difficult to tell from available data whether this signals a less severe deficit or whether it reflects a qualitatively different impairment. There were some notable and interesting differences between E.A. and P.V. in the character of the phonological disorder; for instance, E.A. demonstrated impaired phonemic discrimination (Friedrich et al., 1984) and an inability to make rhyming judgments, while P.V. appeared to be intact in these areas. Thus E.A. would appear to have an impairment at an earlier coding stage than P.V., and that may in turn have consequences for either the severity or the character of the comprehension deficit.

Various aspects of E.A.'s data also argue against an additional syntactic impairment. Although E.A.'s use of semantic constraints in making agent/object role assignments was similar to

the pattern reported for anterior aphasics (e.g., Caramazza & Zurif, 1976), her use of word order information to assign grammatical roles in the absence of semantic cues distinguished her from agrammatic aphasics. Agrammatic aphasics do not seem to use word order information in either comprehension or production, indicating an impairment in mapping thematic information onto constituent word order (Schwartz et al., 1980; Saffran, Schwartz & Marin, 1980; but see also Caplan, 1983). E.A. demonstrated intact syntactic skills in her ability to link the thematic and structural levels through S-V-O role assignments; as a consequence her performance was impaired for passive but not active reversible sentences. Unfortunately, it is unclear whether other patients for whom sentence processing data are available also had a selective impairment for certain surface forms since their results were analyzed on the basis of semantic constraints rather than type of sentence construction.

The repetition data is also relevant to the syntactic impairment issue. E.A.'s performance was quite good under certain conditions and demonstrated considerable ability to understand and produce complex sentence structures. Moreover, performance seemed to break down in a systematic way with increasing complexity, suggesting that E.A.'s ability to process certain features was highly dependent on the complexity of the other features.

Overall, the specific type of errors E.A. made in comprehension, her good performance in production, and the pattern of breakdown in performance as the difficulty of the repetition task increased, seem to reflect an inability to maintain and coordi-

nate different levels of processing simultaneously, specifically when doing so required the retention of a phonological code. In comprehension, lexical meaning and S-V-O mapping dominated the analysis; the simultaneous analysis of the grammatical morphemes that mark syntactic structure in passives was frequently absent. Similarly, E.A. focused more on the lexical value of individual words than on the relational information carried by the spatial prepositions in her interpretation of locative sentences. In production, E.A. selected appropriate lexical items and often generated contextually appropriate constructions but was frequently unable to integrate grammatical markers into her written productions. In repetition, when processing the surface structure made demands on short term memory, E.A. fell back on semantic constraints or the order of nouns in interpreting role relations; her ability to simultaneously recreate the location of the relative clause was highly inaccurate.

What are the implications of these results for models of normal language processing? E.A.'s performance reveals the normal processes that continue to operate despite a deficit in phonological coding and short term memory. The S-V-O and semantic heuristic strategies that E.A. employed emerge early in children's development of syntactic processing and continue in the sentence processing of intact adults (Bever, 1970; Noizet, Dyets & Dyets, 1972). The use of these strategies was perhaps more clear in the case of E.A. than in intact adults because additional syntactic analyses based on surface structure information could not be carried out. In order to interpret a sentence

in which the S-V-O order is violated and semantic constraints are lacking, grammatical morphemes that define the appropriate syntactic structure must be processed. It was these syntactic markers that E.A. often failed to interpret in the comprehension and repetition tasks; as a consequence, the default S-V-O mapping dominated the syntactic analyses. These data suggest that a phonological code, whether generated from auditory or visual input, is the primary means by which important syntactic markers are represented. For intact adults, then, the ability to recompute grammatical roles when the S-V-O mapping is violated and to maintain surface structure information (e.g., specific lexical values and relative clause location) may be heavily dependent upon a phonological representation.

E.A.'s production data demonstrate that the generation of a variety of different syntactic frames can be accomplished without an intact phonological memory capacity. This is consistent with a proposal made by Bock (1982) that subsequent to an early conceptualization stage, semantic representations of lexical items and a syntactic frame are integrated into a phonological representation and articulations are monitored. The errors that E.A. did make in production are consistent with a breakdown at these late stages involving phonological representations: the omission of grammatical morphemes in the more demanding written responses and the occasional mismatching of verbs and prepositional phrases. These results are consistent with Shallice and Butterworth's (1977) findings that the consequences of a deficit in phonological storage are less severe for production than for

comprehension. These findings thus help to define more clearly the different roles that phonological storage plays in the two language functions.

Although the identification of the nature of aphasic impairments is important in its own right, the investigation of cases such as E.A. is a valuable means of uncovering the basic operation of specific processes. In this case, we have been able to identify the independent operation of processes based on representations of semantic information, word order, and grammatical morphemes. The interactions between these processes clearly differ depending upon the nature of the task; it is nevertheless possible to trace the consequences of a basic level impairment as it radiates through the language system.

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Footnotes

1. This work was conducted while the first author was at the Cognitive Neuropsychology Laboratory, Good Samaritan Hospital, Portland, Oregon and was supported by ONR Grant #N-0014-83-K-0601 awarded to Drs. Michael Posner and Steven Keele. The research was also supported by NIH (NINCDS) Grant #19652 to Randi Martin at Rice University. We would like to thank Michael Posner, John Walker and Marilee Zarov for their helpful comments on the manuscript. Reprint requests should be addressed to the first author, who is now with the Department of Psychology, University of Utah, Salt Lake City, Utah 84112.

2. As we are using it, the term 'phonological code' refers to an internal representation that is speech-based and can be activated by either auditory or visual input. The exact form of the phonological code, in terms of whether it is more auditory or articulatory in character, has not been resolved; recent research suggests that it is 'accessible' to both types of information (Salame & Baddeley, 1982). It is important to note that from a linguistic point of view the meaning of 'phonology' is somewhat different. In the context of a grammar, the phonological system refers to a set of rules that specify permissible combinations of features, permissible sequences of these combinations, stress assignment, etc. Although the two concepts are related, they represent very different approaches to the analysis of deficits; thus, the phonological deficit that Kean (1977) has ascribed to agrammatic patients is not directly comparable to a coding deficit as it is discussed here.

3. There is a great deal of evidence that during comprehension the semantic and syntactic features are recovered word by word and as much analysis as possible is carried out at any point in the sentence (Marslen-Wilson & Welsh, 1978; Marslen-Wilson & Tyler, 1975; Just & Carpenter, 1980). These findings might be taken to imply that a verbatim memory for the sentence would be of little use. However, for a large proportion of sentences there are ambiguities in word interpretation that must be resolved by comprehension of subsequent words. Interpretations that are made early on may also have to be revised later. This re-interpretation occurs not only with garden path sentences based on lexical ambiguity (e.g., "I was afraid of Ali's punch because it contained too much alcohol.") but in more mundane instances such as passive sentences, in which the listener may interpret the first noun to be the logical subject but will later have to revise this interpretation to make the first noun the logical object. Even the interpretation of the "was" in sentences beginning with a noun phrase (e.g., "The girl was...") is ambiguous. The "was" could be introducing a passive construction (e.g., was hit), or a progressive verb (e.g., was running), or could be a form of the main verb "be" followed by an adjective (e.g., was happy). If the listener has to store information for subsequent disambiguation, or has to back up and reinterpret a portion of a sentence, a verbatim representation of the sentence would be needed until the final assignments of role relations have been made.

TABLE I

Sample sentences and distractor types used in comprehension tasks.

	Condition		
1.	AL	Active -	The dog splashed the boy.
		Lexical distractor:	(The car splashed the boy.)
2.	PL	Passive -	The boy was splashed by the dog.
		Lexical distractor:	(The car splashed the boy.)
3.	AR	Active -	The ball hit the car.
		Reversal distractor:	(The car hit the ball.)
4.	PR	Passive -	The car was hit by the ball.
		Reversal distractor:	(The car hit the ball.)
5.	LO	Locative -	The block is in front of the ball.
		Object distractor:	(The block is in front of the pyramid.)
6.	LP	Locative -	The block is in front of the ball.
		Preposition distractor:	(The block is below the ball.)
7.	VR	Action verb -	The circle kisses the square.
		Reversal distractor:	(The square kisses the circle.)
8.	LR	Locative -	The square is outside the circle.
		Reversal distractor:	(The circle is outside the square.)

TABLE 2

Error Data - Comprehension Tasks

	AUDITORY				VISUAL			
	Session #				Session #			
	1	2	3	% errors overall	1	2	3	% errors overall
ONDITION								
ctive-Passive								
AL			-0/8	0%			-1/8	12%
PL			-0/8	0%			-0/8	0%
AR	-1/12	-2/12	-0/12	8%	-0/12	-0/12	-1/12	3%
PR	-3/12	-5/12	-4/12	33%	-3/12	-2/12	-2/12	19%
ocatives								
LO			-0/8	0%			-0/8	0%
LP			-0/8	0%			-0/8	0%
VR	-1/24	-2/24		6%	-1/24	-0/24		2%
LR	-6/24	-6/24	-2/8	25%	-2/24	-2/24	-3/8	12%

TABLE 3

Examples of sentence types used in Task 6*

Semantically Irreversible

SF-RB: The boy is eating the apple that is red.

SF-CE: The boy that is eating the apple is tall.

OF-RB: The apple is red that the boy is eating.

OF-CE: The apple that the boy is eating is red.

Semantically Reversible

SF-RB: The monkey is scaring the cow that is yellow.

SF-CE: The cow that is scaring the monkey is yellow.

OF-RB: The cow is yellow that the monkey is scaring.

OF-CE: The cow that the monkey is scaring is yellow.

Semantically Improbable

SF-RB: The worm is eating the bird that is blue.

SF-CE: The worm that is eating the bird is old.

OF-RB: The bird is blue that the worm is eating.

OF-CE: The bird that the worm is eating is blue.

*The following abbreviations are used here: SF = Subject Focus, OF = Object Focus, RB = Right branching, CE = Center-embedded.

TABLE 4

Repetition Data-Semantic Analysis*

	IRREVERSIBLE	REVERSIBLE	IMPROBABLE
Subject Focus			
Right-branching	0.96(1.00)	0.92(0.96)	0.38(0.46)
Center-embedded	0.96(0.96)	0.58(0.67)	0.33(0.38)
Object Focus			
Right-branching	0.79(0.83)	0.50(0.50)	0.38(0.50)
Center-embedded	0.54(0.79)	0.17(0.25)	0.25(0.29)

*Scored according to strict criteria. Scores for lenient criteria are given in parentheses. These scores represent the percent correct for semantic links in the repetition responses.

TABLE 5

Repetition Data-Sentence Structure Analysis **

	FOCUS		CLAUSE LOCATION	
	#SF	#OF	#CE	#RB
IRREVERSIBLE				
SF-RB	8*	0	0	8*
SF-CE	8*	0	8*	0
OF-RB	5	2*	5	2*
OF-CE	7	1*	5*	3
REVERSIBLE				
SF-RB	7*	0	0	7*
SF-CE	6*	0	6*	0
OF-RB	7	1*	6	2*
OF-CE	4	1*	2*	3
IMPROBABLE				
SF-RB	4*	0	0	4*
SF-CE	3*	1	4*	0
OF-RB	6	2*	4	4*
OF-CE	5	3*	6*	2

**Each of E.A.'s responses was evaluated according to relative clause focus and location. The number of responses (out of 8) that used the correct structural form are indicated with asterisks. Since some of E.A.'s responses were incomplete sentences or did not use a relative clause, the sum of the two focus categori or the two location categories may be less than 8.